[0011] Magnetic field region 18 is a band of asymmetric conductance region 12 subjected to a localized magnetic field B oriented normal to the plane of thermoelectric structure 10 and out of the page, as depicted in FIG. 1. This magnetic field may be provided by depositing and polarizing magnetic material 28, a thin layer of magnetic material located atop and/or beneath the plane of thermoelectric structure 10, adjacent magnetic field region 18. Alternatively, magnetic field B may be an external field from, e.g., a magnetized coil. Magnetic field B is herein assumed for simplicity to be substantially uniform within magnetic field region 18, although all implementations of magnetic field B will of course vary somewhat over magnetic field region 18. Collimating regions 20 and 22 are bands of asymmetric conductance region 12 situated between magnetic field region 18 and shorting bars 14 and 16, respectively. Collimating regions 20 and 22 are regions with negligible magnetic field that serve to collimate ballistic charge flow between shorting bars 14 and 16 (in either direction).

[0012] Collimating regions 20 and 22 feature collimating guides 24, while magnetic field region 18 features curved guides 26. Collimating guides 24 and curved guides 26 are physical discontinuities along lines in thermoelectric structure 10 that act as scattering barriers to form channels in collimating regions 20 and 22 and magnetic field region 18, respectively, by ballistically scattering incident charge carriers. Adjacent collimating guides 24 may, for instance, be separated by a distance of approximately 1 nm-approximately 1 μm along an axis parallel to shorting bars 14 and 16, depending on the material and operating temperature of thermoelectric structure 10. Adjacent curved guides are separated by a similar distance. Collimating guides 24 and curved guides 26 may be created in a variety of ways, including by laser or mechanical scribing, surface level doping, field doping, or lithographic patterning. Collimating guides 24 are straight, parallel lines that act to focus charge carrier trajectories in collimating regions 20 and 22 along transport direction T or the opposite direction, −T. Curved guides 26 focus charge carriers moving in transit direction T from shorting bar 14 to shorting bar 16, but act to continually frustrate charge transport in opposite direction −T, as described in further detail below. Collimating guides 24 and curved guides 26 extend throughout the entire thickness of thermoelectric structure 10.

[0013] It is well known from elementary physics that a charge carrier of charge q, when travelling with vector velocity v through a magnetic field characterized by vector B, will experience a Lorentz force:

$$F=qv\times B. \quad \text{[Equation 4]}$$

[0014] A charge travelling in a plane through a magnetic field normal to that plane thus experiences a Lorenz force qvB in the plane and at right angles with v. The direction of curvature of a charge trajectory due to Lorenz force is opposite for conductors travelling with velocities v and −v, and of opposite signs q and −q. As depicted in FIG. 1, an electron travelling in transport direction T will deflect to the left under magnetic field B, while an electron travelling in the opposite direction −T will deflect to the right under magnetic field B. Curved guides 26 take advantage of this broken symmetry by allowing substantially unobstructed electron flow in transit direction T while frustrating electron flow in the opposite direction −T. Curved guides 26 form parallel curved channels in magnetic field region 18 that coincide with the arcs of curvature of forward conduction (i.e. in transit direction T), and thus more closely match the natural deflection trajectories of negative charge carriers moving in transit direction T than in the opposite direction −T. Thus, electrons travelling in transport direction T scatter on curved guides 26 substantially less and at wider angles than electrons travelling in the opposite direction −T. This asymmetry results in longer ballistic trajectories in the −T direction than in transmit direction T, with corresponding forward electrical conductivity $\sigma_{forward}$>reverse electrical conductivity $\sigma_{reverse}$. This behavior is illustrated and described in further detail with respect to FIGS. 2A and 2B.

[0015] FIGS. 2A and 2B depict ballistic trajectories of negative charge carriers such as electrons through magnetic field region 18. FIG. 2A shows the trajectory of a charge carrier moving in transport direction T, while FIG. 2B shows the trajectory of a charge carrier moving in opposite direction −T. In both cases the Lorentz force causes the charge carrier to deflect in a counter-clockwise direction, according to the right-hand rule. In FIG. 2A, the charge carrier is deflected substantially to the right along a path defined by curved guides 26, and scatters at large angles with respect to curved guide 26. This scattering adds relatively little to the total path length of the charge carrier trajectory in FIG. 2A, corresponding to a high value of forward electrical conductivity $\sigma_{forward}$. In FIG. 2B, by contrast, the charge carrier is deflected substantially to the right, and scatters several times at progressively smaller angles with respect to curved guides 26. This scattering dramatically lengthens the total path length of the charge carrier trajectory in FIG. 2B, corresponding to a low value of reverse electrical conductivity $\sigma_{reverse}<\sigma_{forward}$.

[0016] Thermoelectric structure 10 enables high values of ZT. Magnetic field regions 18 with perpendicularly applied magnetic fields B and curved guides 26 coinciding with arcs of curvature of charge carriers traveling in transport direction T can yield ratios of forward to reverse conductance $\sigma_{forward}/\sigma_{reverse}$~10, potentially enabling the creation of ZT>5 thermoelectric materials which would fundamentally change the coefficient of performance of solid state materials, potentially opening up their use for all solid state commercial refrigeration systems.

[0017] While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

The status of the claims is as follows:

1. A thermoelectric structure comprising:

a thin thermoelectric film extending in a plane between parallel first and second shorting bars; and

a plurality of curved ballistic scattering guides formed in a magnetic field region of the thin thermoelectric film subjected to a local, substantially uniform, nonzero magnetic field normal to the plane of the thin thermoelectric film.

2. The thermoelectric structure of claim 1, wherein the shape of the curved ballistic scattering guides substantially matches an arc of curvature of a charge carrier travelling in a